NASA-CR-200902

Technology for Developing Reusable Sharable Engineering Models

Final Report

Edward A. Feigenbaum, Co-Principal Investigator
Richard E. Fikes, Co-Principal Investigator

Knowledge Systems Laboratory
Stanford University
(415) 723-3444

NASA Grant NCC 2-537

April 1996

Research Objectives:

The objectives of this research are to: (1) develop a methodology and a computational framework that will enable engineers to access a comprehensive and reusable body of engineering knowledge and reasoning methods for a wide variety of tasks; and (2) develop techniques for (a) building ontologies in a form that is translatable into the specialized representation languages of multiple application system environments, and (b) interchanging the reusable content of knowledge bases, including ontologies, among specialized representation languages.

Impact

This research will enable NASA engineers to formulate models of devices and construct simulations rapidly, to capture and use the symbolic knowledge of engineering practice (e.g., design rationale), to demonstrate and automatically explain the behavior of devices and systems at multiple levels of abstraction, and to use knowledge bases interchangeably among different reasoning systems.

Approach:

To reach the above objectives, the project focussed on supporting design and redesign of electromechanical devices by providing effective tools for simulating and analyzing the behavior of such devices in all stages of their design. Asmall number of interesting devices were selected as drivers of the research. Research results are incorporated in an evolving "designer's associate" system called the Device Modeling Environment (DME). The project has also developed a logic-based interlingua called "KIF" for communicating encoded knowledge, semi-automatic systems for translating knowledge bases into and out of the interlingua, and an integrated tool system called "Ontolingua" for specifying domain-specific ontologies in KIF. Ontolingua includes facilities for translating the resulting ontologies into application-oriented representation languages, such as CLIPS and IDL.

Summary of Achievements:

Device Modeling and Analysis

Compositional Modeling Language

- Completed a draft specification for version 1.0 of a common Compositional Modeling Language (CML) in collaboration with Xerox PARC, Northwestern University, and the University of Texas.
- Released the specification for CML 1.0.
- Improved automatic model composition techniques and demonstrated the new techniques with an initial implementation (Levy, et al. 92; Iwasaki & Levy 93).
- Installed CML in the Device Modeling Environment as the device modeling language.

Device Modeling Environment

- Extended our implementation of a method for testing whether simulator output satisfies a functional specification and began incorporation of this method into DME.
- Designed new representation and user interface facilities suitable for incorporation into DME to support the design process of successively refining and evolving the functional and structural specifications of the desired artifact (Iwasaki et al 93).
- Augmented DME's interactive causal explanation facilities so that the system can dynamically generate hypertext explanations containing links to related and more detailed explanations. Put an initial demonstration of this capability on the World Wide Web containing explanations of a simulation of the Reaction Control System in NASA's space shuttle.
- Published papers in the AAAI'93 and IJCAI'93 conference proceedings on DME's interactive causal explanation facilities (Gruber & Gautier 92; Gautier & Gruber 93).
- Augmented the control structure of DME to enable automatic exploration of alternative simulation scenarios.
- Constructed an initial version of a knowledge base in the thermal engineering domain for analyzing the performance of thermal plants operating in steady state.
- Developed an initial set of tools for authoring interactive documentation of device designs that includes a knowledge base of DME device models, functional specifications, and simulation scenarios.

Functional Representation of Devices

- Refined and extended the expressive power of the Causal Functional Representation Language (CFRL) for specifying the intended functionality of a device (Iwasaki et al. 94; Vescovi et al. 93).
- Described in a published paper how functional representation languages such as CFRL can be used for recording important aspects of design rationale in a form that can be manipulated computationally (Chandrasekaran et al. 93).
- Completed initial design and prototype implementation of a user interface for specifying device functionality using CFRL.

Device Diagnosis

- Designed an integrated framework based on Bayesian Networks for diagnosing engineering systems (Srinivas 93a, Srinivas 93b).

Knowledge Sharing Technology

Knowledge Interchange Format

- Identified Definite Clause Translation Grammars (DCTG's) as a suitable grammar formalism for translating knowledge bases into and out of KIF.
- Developed a method for determining whether a DCTG for translating into KIF is reversible so that it can also be used for translating out of (a subset of) KIF (van Baalen & Fikes 93), and
- Implemented an interpreter for DCTG's in the KIF-based translation shell.
- Developed an initial version of a context-based formal framework for describing translations between ontologies and syntactic sublanguages within the interlingua (Buvac & Fikes 93).
- Exemplified the use of KIF to specify the semantics of representation languages by defining the semantics of CML in terms of KIF axioms and by using a CML-to-KIF translator to help debug both the language design and the semantic specification.
- Developed, in collaboration with the Interlingua Working Group, a working draft for an American National Standard for KIF. A draft document has been written that represents the consensus of the X3T2 Ad Hoc Group on KIF as of March 1995 (see http://logic.stanford.edu/kif/specification.html).

Ontology research

- Increased the utility of the Ontolingua system by adding new tools for developing and translating portable ontologies (Gruber 93b).
- Added to the Ontolingua system a facility for generating hypertext webs of ontologies in the format of the World Wide Web (WWW).
- Ontolingua is now being used in scores of projects around the world, including a joint project with Lockheed, an experimental testbed for configuration design, and a shared ontology for spacecraft operations (European Space Agency).
- In collaboration with the Stanford Mechanical Engineering Department, continued the development of ontologies that provide knowledge-level descriptions of engineering mathematics, and used those ontologies as the declarative user language for a mathematical analysis server.
- Created and maintained a library of ontologies and knowledge sharing documents publicly available by ftp.
- Proposed evaluation criteria for ontologies and discussed the rationale for two ontologies developed at the KSL in light of these criteria (Gruber 93a).
- Upgradedthe knowledge sharing library to be a World Wide Web server that will provide hypertext versions of papers and directories, and fully cross-indexed ontologies.
- Developed Ontolingua translators to IDL and to Clips (the public-domain, C-based frame system developed and used at NASA).
- Explored the use of knowledge sharing technology to support computational agents that provide services which involve obtaining information from multiple databases and knowledge bases having different underlying ontologies and query languages. Such an agent uses a *domain-specific interlingua* consisting of KIF and a set of ontologies to interact with its users and with its data and knowledge sources. The agent performs the necessary translations into and out of its domain-specific interlingua when interacting with its information sources.

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